Near-Infrared Reflectance Spectroscopy for Predicting Lipid Content in Chicken Breast Meat

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Abbreviated title: NIRS and meat lipid content

Within the framework of a project requiring an important number of measures of lipid content in chicken breast meat, near-infrared spectrometry (NIRS) was tested in order to avoid the use of the reference extraction method requiring long analytical process. Two methods were compared: direct spectrum acquisition with a fibre optic probe on breast muscle, 24 h after slaughter and just after the cutting and boning process (spectrometer ASD, Labspec Pro) or later in the laboratory on ground breast meat (spectrometer Büchi). The direct spectral acquisition was realised on 877 fillets of broilers issued from different slaughter plants. The laboratory spectral acquisition was realised on the same 877 fillets plus 457 other samples also issued from different slaughter plants. Calibration equations established with ground meat were more precise. SECV (standard error of cross-validation) was 0.24% (R^2=0.83) for lipids, which is equivalent to the repeatability of reference measurements (0.20%). The direct measurements on breast muscle led to a less precise calibration equation (lipids: SECV=0.37%, R^2=0.68). In conclusion, the prediction of lipid content with NIRS provided satisfactory data when spectra were realized in the laboratory on ground breast meat. Direct measurement was less precise, but allowed a useful *in situ* estimation of the chemical composition.

Keywords: chicken; meat; quality; lipids; NIRS

Introduction

The determination of meat chemical composition is necessary to control product quality in food-processing industries or in the frame of scientific studies concerning nutrition or genetic parameters. The most common measurements are water, lipid or protein content and sometimes more specific components such as fatty acids. These chemical analyses do not present much difficulty, but as soon as a large number of samples is concerned, they represent a lot of work, are costly, and require long delays before obtaining results.

Near-infrared reflectance spectrometry (NIRS) is an analytical method based on light absorption (□=800-2500nm) by organic material. The absorption level is related to the nature and quantity of chemical links and then to the chemical composition of product. After calibrating the equipment the measurement is easy and quick, allowing the prediction of chemical composition of hundreds of samples with a low cost. It is also possible to install online systems directly in the food-processing industries. This technique was yet tested to estimate meat quality (Prevolnik *et al.*, 2004) in many cases, included chicken meat (Windham *et al.*, 2003).

The present study was conducted in the framework of a large survey in different French slaughterhouses in order to determine the variability of breast meat quality from chickens reared under different production systems (standard, "Label Rouge") in which it was necessary to determine the lipid content of a high number of breast muscles. In the present methodological study, we compared different equipments and different methods for spectra acquisition in order to optimize the use of NIRS for the prospective applications.

Materials and methods

In 2008, 877 breast samples from heavy standard chickens were used. In 2009, 457 breast samples from Label Rouge chickens were analysed. The breasts were obtained from different slaughter plants. A first spectrometric measurement was done 24 h after slaughter and just after the cutting and boning process directly on the breast muscles (*Pectoralis major*) collected in 2008. Meat samples (about 60 g per sample) from 228 and 271 breast muscles in 2008 and 2009, respectively were ground and stored at -20°C for further spectrometric and chemical analyses.

Two spectrometers were used: laboratory equipment Nirflex N-500 (1000-2500 nm) with a module for solid analysis, and portable equipment ASD Labspec Pro (350-2500 nm) with a « contact probe » module. All measurements were done in reflectance mode.

Two types of spectrometric measurement were done:

- Direct measurement on breast muscle with the ASD spectrometer just after cutting and boning carcass at 4°C, 24 h after slaughter. For each breast muscle, 8 spectra (4 measurement points on each breast repeated twice) were taken. The points were standardised (upper, right, left and down part of the internal side of breast).
- Measurement with the Büchi spectrometer was realised on ground breast muscle after thawing 12 h at 4°C, and presented in glass Petri dish (diameter=9 cm). Each sample was measured three times (different cup filling) and spectra were averaged.

All the breast samples previously collected were analysed with the reference laboratory methods: cold lipid extraction with chloroform-methanol (Folch *et al.*, 1957) and moisture (oven at 104°C until a constant sample weight). The analyses were done in duplicate on some samples in order to calculate the repeatability of the laboratory measurements.

The spectral data acquired with ASD spectrometer were treated with WINISI software (Infrasoft Int., Port Matilda, PA, USA). The spectral data acquired with the Büchi spectrometer were treated with Nirware software. For ASD equipment, the visible wavelengths (400-800 nm) were not used in order to avoid too sensitive models taking into account colour differences not induced by chemical composition. The wavelengths presenting too much noise (>1800 nm) were also discarded from the analysis. The mathematical pre-treatment of spectra was determined in order to optimize the model performances. For the spectral data acquired with ASD spectrometer, the optimal pre-processing was found to be the 1st derivative after normalization and smoothing on 10 measurements (WINISI SNV procedure 1, 10, 5). For the spectral data acquired with Büchi spectrometer the optimal pre-processing was found to be the 2nd derivative after normalization and smoothing on 9 measurements (Nirware SNV procedure 2, 9, 3).

The calibration equations were developed by Partial Least Square (PLS) regression. The calibration performances were described by their coefficient of determination (R^2), and their residual standard error of calibration (SEC) and cross validation (SECV). The ratio RPD = SD/SECV was calculated as a synthetic criterion of model quality for the spectral data.

The validation procedure was realised according two steps. First, we tested a cross-validation. As each sample was measured three times we compared our database containing two repetitions with the

data representing the third repetition. Then, we made a true validation with new independent samples. For this purpose, we used our database to predict the lipid content of 698 breast muscles collected in 2009 from an experiment on "Label Rouge" chickens. Among these samples, 35 were analysed with the reference Folch method and we compared the measured data we the estimated data.

Results and discussion

The spectra obtained with the two equipments had the same general aspect (Figure 1); they were characterized by high absorption peaks for water (980 nm, 1450 nm, 1950 nm).

The most precise prediction for lipid content was obtained with Büchi spectra measured on ground samples. This result seems to be logical because these spectra were obtained under standardised conditions on homogeneous samples and similar to those used with the usual laboratory reference method. Under these conditions, the SEC was 0.21%, value similar to the repeatability obtained with the laboratory reference method (0.20%). The cross-validation (SECV) gave an error of 0.24% (R^2=0.83) and the RPD value was 1.95. Figure 2 shows the relationship between the predicted and measured lipid contents. Under similar conditions, Cozzolino *et al.* (1996) obtained SECV=0.54% in chicken meat. Berzaghi *et al.* (2005) obtained 0.24% but with a relatively low number of samples.

For moisture level, the model obtained with Büchi spectrometer had a SEC = 0.46% and a SECV = 0.50% (R^2= 0.44). The relative weakness of RPD (0.58) was due to the low variability of the database. The precision of moisture level measurement also depended on the storing conditions of samples. Spectral measurements were done with thawed samples; therefore free water could interfere with NIRS measurements. However, the calibration performances obtained for moisture in our study were a bit better than those reported by Cozzolino *et al.* (1996, 0.70%) but lower than those from Berzaghi *et al.* (2005, 0.19% for dry matter) on chicken meat.

The spectra measured directly on breast muscles, just after carcass cutting with ASD spectrometer gave less precise calibrations than those obtained with Büchi spectrometer on ground samples. The SEC and SECV values obtained for lipids (0.31 and 0.37%, respectively with R^2=0.68) were higher and the RPD value (1.51) was lower than those obtained with ground samples.

For the true validation, the average value and standard deviation for lipid content of breast muscle were 1.04 ± 0.23%. Because of a low variability of values we compared estimated data with measured data on the same samples using a Chi 2 test. The P value was 0.26 showing no difference between the two sets of values and validating the reliability of our prediction method.

Conclusion

This study confirmed the feasibility of NIRS measurement to determine moisture and lipid levels in chicken breast muscle. It allowed to specify the optimal measurement conditions and showed that the predictions obtained with ground samples in the laboratory were better than those determined directly on breast muscles in the slaughterhouse. However, the measurements on the whole breast muscles with portable equipment gave calibrations with a reasonable precision. The spectra measurement with ASD equipment is fast and does not require any sample preparation. Therefore, this method can be interesting for practical applications under industrial conditions. The prediction model allowed predicting the lipid level for 2034 chicken breast muscles from different origins.

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Figure 1 Spectra from ground chicken breast muscle obtained with Büchi spectrometer

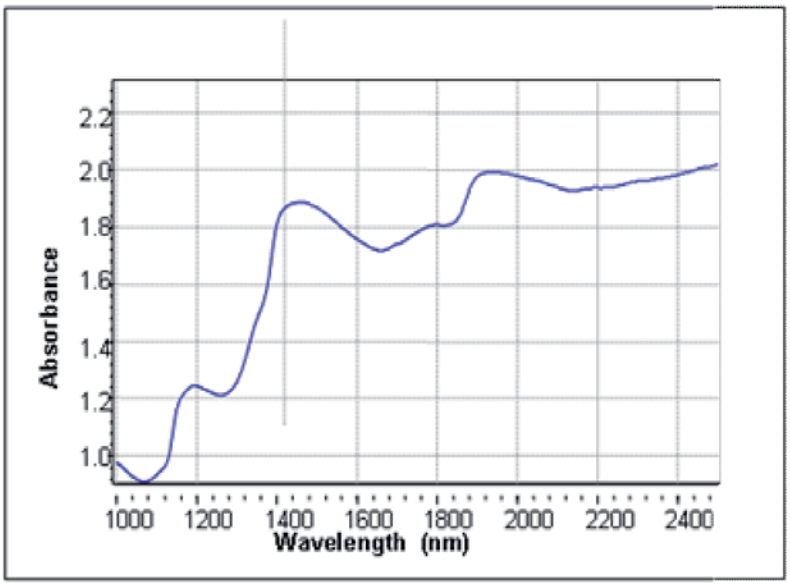

Figure 2 Relationship between the predicted and measured lipid content in breast muscle of chicken